DOES THE DELAWARE WATER GAP CONSIST OF TWO RIVER GORGES?

BY EMMA WALTER.

The Delaware River passes through the Kittatinny or Blue Mountain by a cleft nearly at right angles to the axis of that range. The entire length of the cut is a little over two miles, but only to the part where it is narrowest or its walls highest and steepest is the term "Water Gap" locally applied. In the following paper, when the Gap is mentioned the entire two miles is included.

It is clear this remarkable breach in the mountain has been made by river water, and that it is still being deepened by the Delaware, as is stated in the Reports of the Pennsylvania Geological Survey.

But a study of the marked features of the Water Gap has convinced me the Delaware once flowed through it from the south towards the north, or in a direction directly opposite to the present flow of the river; also that this north-flowing river was preglacial and that much the larger part, both of the length and depth of of the Gap, was cut by this old river, the remainder being the work of the present south-flowing river since the Ice Age, the Delaware Water Gap being thus composed of two united river gorges, which have been cut from opposite directions.

If we examine the work of streams which are now forcing their way through hills or mountains, we will see all do their work upon much the same pattern; that is, a gorge with a funnel-shaped entrance opening down stream and contracting to a passage with more or less precipitous sides that suddenly expand into an amphitheatre with very precipitous walls. The curve of this amphitheatre always points up the stream, and over the centre the waters tumble into a pool, the depth of which, at the foot of the fall is often very great, even when the stream is quite shallow in all the rest of its course.

The upper portion of the Delaware Water Gap is just such a gorge, but its funnel-shaped entrance points *up* stream and not *down*, as it should if it was the work of the present river. Its amphitheatre rounds *down* stream instead of *up* as it would if it had been cut by

our Delaware. Near the northern entrance to the Water Gap are low rapids, over the Clinton rocks; just after the river accomplishes its passage through the mountain it falls in a succession of low rapids over the Hudson River slates.

For many miles both above and below these two sets of rapids the average depth of the water is only six feet, according to the Geological Survey, but between them, about a mile and three-quarters below the upper, and a quarter of a mile above the lower rapids, is a spot where the river has a surprising depth; no two authorities agree concerning the number of feet. In 1892 the engineer of the little launch which plies to and fro in the Gap, said: "It is 35 feet deep." L. W. Brodhead writes me: "We took soundings about forty years ago and made it 45 feet;" and he adds, "a sounding some years previous reached 60 feet, while a century earlier it was thought to be unfathomable." In Penna. Geol. Sur. Rept's., Vol. G6, the depth is given as 51 feet, while a local Guide Book gives 70 feet.

Two agencies are, no doubt, slowly lessening this remarkable depth. The gradual cutting down of the whole river bed from this point to sea level and the slow filling of the pool, by the debris dropped into its quiet waters in times of freshet.

At the north entrance of the Water Gap the bed of the river is nearly 1,500 feet wide; in half a mile it has contracted to 400 feet and in the next mile reaches its narrowest, 350 feet. This portion is nearly a quarter of a mile in length, its walls, 1,000 feet high, rise at an average angle of 45°. From 350 feet the channel suddenly widens to an oblong pool 500 feet wide and about 900 feet long. This pool is bounded by nearly 900 feet of Pennsylvania shore which rises, steeply, to a height of 1,100 feet. The New Jersey side stretches in a beautiful curve, 2,100 feet long, and rises in part a sheer precipice of 1,000 feet, with 200 feet of steep rock still above that. This great curve rounds to the south and ends suddenly at the Point of Rocks. It is just opposite this point and not far from the New Jersey shore, the extraordinary, deep water before described is found. Here, I believe, is the centre of the amphitheatre of the gorge of the north-flowing Delaware and this deep pool marks the spot where the waters of the great river plunged into the chasm. But the solid rock wall over which they fell has been breached by a channel 400 feet wide. Through this opening

the Delaware enters that portion of the Water Gap that I believe is the work of the present south-flowing river.

Nor is the character of the part of the Gap just described the only evidence that the Delaware River in pre-glacial times flowed to the northward.

In Vol. G6, page 53, we read, "finding an old buried valley bed from Port Jervis northeastward to the Hudson River at Rondout, * * * the suggestion seemed not unreasonable that the Delaware turned northeastward at Port Jervis and, receiving a large tributary from the south, kept along this old buried valley to the Hudson River. "But," the report continues, "subsequent study of the Delaware Valley, southward * * * seemed to render this view uncertain, since the Delaware appears to have flowed through the Kittatinny Mountain, at the Water Gap, during its entire history."

I think it is clear "the Delaware has flowed through the Gap during its entire history," but that the direction of the flow of the river through the Gap in pre-glacial times was exactly the reverse of its direction since the glacier disappeared.

In Vol. D3, of Penn. Geol. Sur. Rept's., two remarkable patches of gravel are described. One is at West Bethlehem, the other at Easton. Both lie at a height of 170 feet above the present level of the water in the Delaware at Easton. Upon this gravel rests a boulder clay which contains scratched stones, gravel and clay, together having a thickness of from 25 to 30 feet. The irregularities of the upper line of the gravel are great and show it was worn into hollows before the clay was deposited. "This gravel," says the report, "is unquestionably a river deposit, a fragment of an ancient river terrace, and could only have been formed by the damming back of descending waters; but there is no evidence of such a dam and no known means for producing it below Easton."

If the Delaware, at the time it was depositing this gravel was "descending" towards the north, then it is *above* Easton and not *below* that we must look for the means for producing such a dam.

I think we can find both the "means" and the place, and that they explain not only the gravel but also the boulder clay which lies on top of it. The "means" is the great Ice Sheet, moving southward; the place, where this Ice Sheet effectually blocked the northward flow of the Delaware. This, undoubtedly, would be at the Water Gap. But, manifestly, a great river flowing far to the north-

ward would meet the glacier long before the ice reached the Gap. Possibly the river might find, for a time, a side escape for its waters, without turning back upon itself. As Prof. J. P. Lesley says, on page 1,203 of Summary, Final Report, Penn. Geol. Sur. "the Delaware River seems to have flowed in different ages along different lines." When the ice at length filled the Gap, which is about twenty-three miles above Easton, then the river waters would be ponded back upon themselves and all the debris carried by the stream, still flowing from the south, would be dropped where the currents meet. When the ice finally reached its southern limit, marked by the terminal moraine which lies 12 miles above Easton, then, what H. Carvill Lewis, in his "Glacial Geology of Great Britain and Ireland," styles an "extra-moraine lake" would be formed. For he says: "when glacier or moraine obstructs a stream flowing from outside towards the glacier a lake may be formed in the non-glaciated area bordering the moraine. Such lakes are only temporary and are drained when the river has established its new channel." "At first thought," Mr. Lewis continues, "it seems a remarkable feat for a river to suddenly begin flowing backward and up stream; but I can show that this feat was actually accomplished in many cases, both in America and England," and farther, "a river having begun to flow backward while the ice barred its forward progress, continued to do so after the ice-wall had retreated and the terminal moraine took its place." On another page we read in the same work, "when a stream was dammed back by the front of the ice, there boulder clay full of scratched erratics accumulated, filling the old river valley."

The change in the direction of the flow of the Delaware was no doubt accelerated by the general change in the level of the land which we know accompanied the Ice Age, an elevation at the north and a depression at the south. In "Glacial Geol. G. Brit. and Ire." before quoted, it is stated, "there was in Pennsylvania a subsidence of 180 feet at tide-water. The rivers then emptied much further inland and their channels were much shorter and relatively steeper than now and thus their cutting power would be largely increased." The great volume of water loaded with debris which must have issued from the melting ice sheet would also add greatly to the rapidity with which a new channel would be cut.

In a note in 2d Geol. Surv. Penna. Rep't, Vol. L, Prof. J. P.

Lesley calls attention to the curious fact that the gravel deposit at Easton stands nearly upon the same level with the highest of the Upper Delaware terraces above that river.

The terraces of the Upper Delaware are a marked and beautiful feature of its scenery. They are found between Port Jervis and the Water Gap, often as four regular steps. The first or lowest is from 20 to 25 feet above the river, while the fourth or highest terrace stands at 150 feet above the present river level. Five terraces are all well marked along Brodhead's Creek, the principal tributary of the Delaware between Port Jervis and the Water Gap. They can also be traced up the "great buried valley" in which the sluggish stream known as Cherry Creek flows to enter the Delaware just below the mouth of Brodhead's Creek and just above the northern entrance to the Gap.

In Report L, Prof. Lewis says, "these terraces of the Upper Delaware may be due to an ancient obstruction in the Gap backing up the water from the melting glacier to form a lake of considerable size." That these terraces are of later formation than the glacial deposits is proved on Brodhead's Creek, where a railroad cutting shows kames partly covered by terrace material.

Now it will be remembered their positions are directly reversed at Easton; there the glacial material lies on the top of the river terrace, showing that the terrace there is the older deposit of the two.

If the rock in the centre of the amphitheatre of the pre-glacial gorge had not been cut down to present river level, when the glacier retreated this rock-wall would certainly stand as "an ancient obstruction in the Gap, damming back the waters to form a lake of considerable size," or from Port Jervis to the Water Gap. In this lake the waters would rise until they reached the top of the rock-wall and pouring over it the draining of the lake would begin. So the highest terrace of the new river would come to stand nearly upon the same level as the lowest or last of the old river, the new standing at 150 feet and the old at 170 feet above the present water level in the river. Does this difference of 20 feet represent the sum of the fall of the bed of the old river between Easton and the Water Gap and the amount of the erosion by the ice between the same points?

In Vol. L, page 58, H. Carvil Lewis says, "it was a surprising and unexpected fact to find no tongue of ice was projected through the Gap, which was, as it were, ignored by the glacier. It filled the

Gap up with ice but moved diagonally across it." Glacial striæ all pointing in a direction obliquely across the mountain and the Gap, occur at various heights and on the top of the mountain, but no striæ were noted below the Kittatinny House. This hotel stands upon the 120 foot contour line of Chance's map, though according to Mr. Brodhead it is 180 feet above the river and is situated just below the north entrance to the Gap.

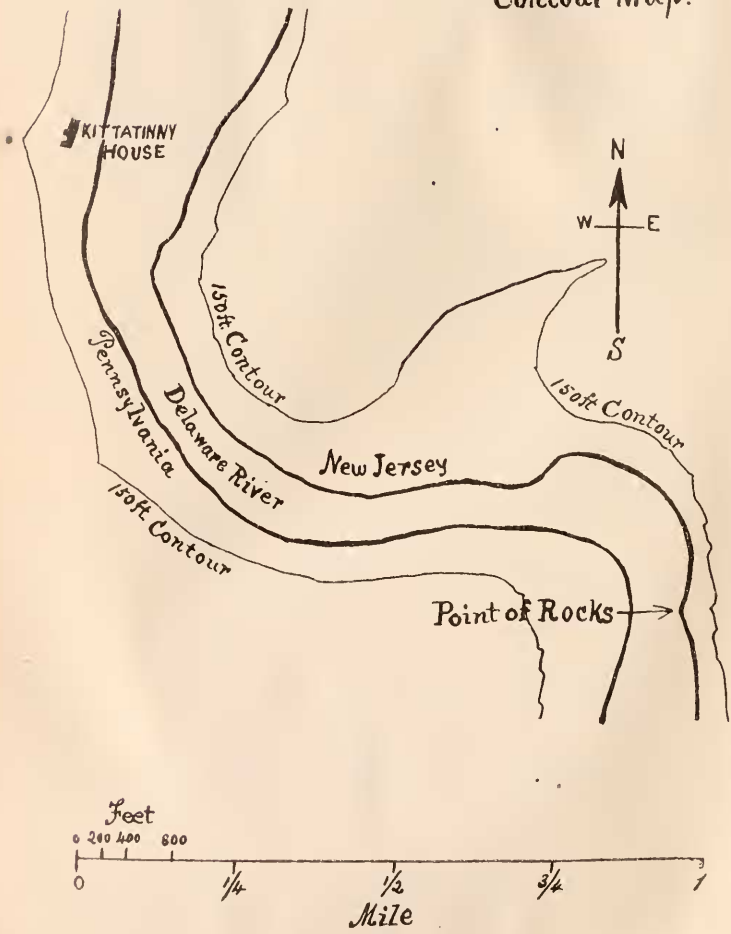
Above the carriage road, on the Pennsylvania side, not far from the narrowest part of the gorge, a series of beautiful, polished, horizontal grooves of considerable size may be seen ; on the perpendicular face of the sand-stone rock, Mr. L. W. Brodhead gives the height of these grooves above river as 150 feet. Their course is nearly at right angles to the direction of the glacial striæ on the mountain.

Whether these are glacial grooves, or whether they are, as seems to me most probable, the result of a swift current of water carrying much debris, they certainly show that a powerfully erosive agent of some kind passed through the Gap at about the height of 150 feet. Now at this same height stands the upper terrace of the present river, while not far above the same elevation lies the old river gravel, and glacial striæ appear to be absent below a nearly equal level. The position of grooves, terrace, old river gravel and absence of glacial striæ, so nearly on the same line, is explained, if the rock wall of the centre of the amphitheatre stood somewhere near a height of 150 feet at the end of the Ice Age.

When the water commenced to flow over this rock-wall it would begin the cutting of the short lower, or south portion of the Gap. Its walls are very precipitious for a short distance and the gorge ends rather suddenly, as the southeastern face of the Kittatinny Mountain is exceedingly bold. This lower gorge extends from the Point of Rocks to the head of the rapids over the Hudson River slates. The width of the channel where the river passes from the upper gorge to the lower, as before stated, is 400 feet, but it increases to 800 feet at its wide-spreading mouth. This very rapid curving outward of the walls of the lower gorge, on both sides of the river so nearly alike, seems to indicate the impetuous rush of an immense body of water.

The difference in the character of the bed of the present river from Port Jervis to the beginning of the Hudson River slates and from the beginning of the Hudson River slates to the

A map of the
Delaware Water Gap.
Reduced from
Chance's
Contour Map.



moraine at Belvidere, I think offers further proof that the first mentioned portion was cut before the coming of the ice sheet, and the last since the melting of the ice; for from Port Jervis to the slates the Delaware flows in a deep, ancient river valley or valleys. Its bed, except at a few points where there is a rock bottom for a short distance, is in the glacial drift which still fills the old water course to an unknown depth, even the deepest portion of the Gap itself being so filled, while from the beginning of the slates to Belvidere, the river has a rock bed, its channel is broad, the valley wide, with hills rising only one or two hundred feet above the river.

Looking southward from the top of Mt. Minsi, on the Pennsylvania side of the southern entrance to the Gap, from a height of 1,100 feet, the country has the appearance of a gently sloping plain nearly to Belvidere, 13 miles away. The fall in the river in this distance is 4½ feet per mile, while in the unglaciated area between Belvidere and Easton the descent is 6½ feet per mile. This fall, with the vast volume of water which must have continually poured through the Gap during the melting of the ice, would certainly, I think, give a torrent of sufficient force to accomplish the work which I have assumed has been done since the melting of the ice sheet.

If I have proven that the gorge from the Point of Rocks to the northern entrance of the Gap was the work of a north-flowing river, and the gorge from the Point of Rocks to the southern entrance of the Gap is the work of the south-flowing Delaware, it follows that the Delaware Water Gap *does* consist of two river gorges united, eroded from different directions and in different geological epochs.